# Genetic fuzzy system modeling and simulation of vascular behaviour

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*Publication date:*
2012

*Document version*
Early version, also known as pre-print

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# Genetic Fuzzy System Modeling and simulation of Vascular Behavior

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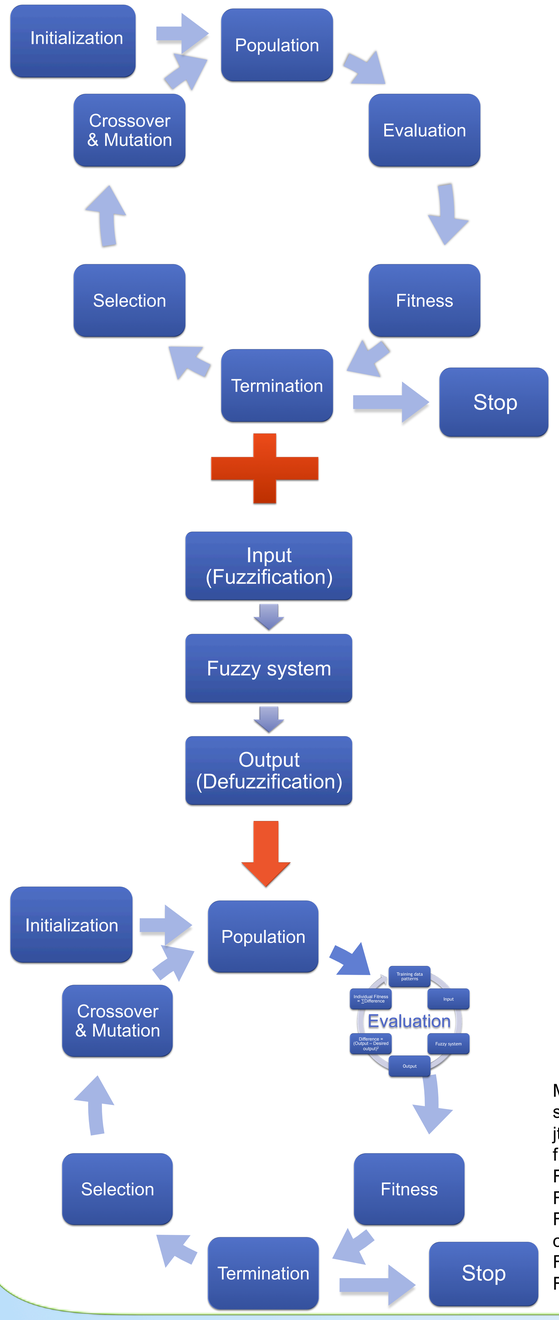
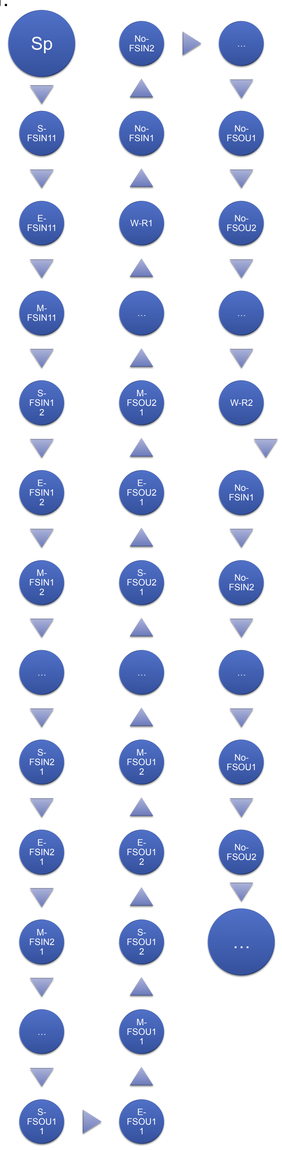
## Introduction

- Purpose--To use a genetic algorithm to optimize a fuzzy system that is capable of describing the pharmacodynamic behavior of small blood vessels, through a computational learning process of experimental data. These fuzzy systems can, in principle, be used to predict, identify or categorize data.
- Hypothesis--Genetic Fuzzy Systems can be used to predict the contractile or pharmacodynamic behavior of small arteries.
- Current Solution--One modeling approach is being investigated, Genetic Fuzzy System (GFS). In Genetic Fuzzy Systems, the model algorithm mimics the biologic genetic evolutionary process to learn and find the optimal parameters in a Fuzzy System that can control the fluctuation of physical features in a blood vessel, based on experimental data (training data). Our solution is to create chromosomes or individuals composed of a sequence of parameters in the fuzzy system and find the best chromosome (individual) to define the fuzzy system as described previously. The model is implemented by combining the Matlab Genetic algorithm and Fuzzy system toolboxes, respectively. All computations were performed on workstation and DCSC cluster.
- Genetic Fuzzy system--




Model of Chro-mosome. Sp:setpoint; S-FSINij: start of jth fuzzy set of input i; E-FSINij:end of jth fuzzy set of input i; M-FSINi:Mememberships function of jth fuzzy set of input i; S-FSOUij:start of jth fuzzy set of output i; E-FSOUij:end of jth fuzzy set of output i; M-FSOUij:mememberships function of jth fuzzy set of output i; w-Rn:weight of rule n; No-FSINij:number of jth fuzzy set of input i; . No-FSOUij: number of jth fuzzy set of output i

## Result

Experimental pressure data of four different isolated small blood vessels, which are from same animal and treated with different agonists, are used to test the performance of GFS. The figures below show the performance of generated fuzzy system with two inputs, Error (E) and change of Error (CE), and one output, pressure. Each input and output has two fuzzy sets. The fitness of the fuzzy control system generated by learning in each generation is tested not only in training blood vessel (Interpolation) but also other blood vessels (Extrapolation) .

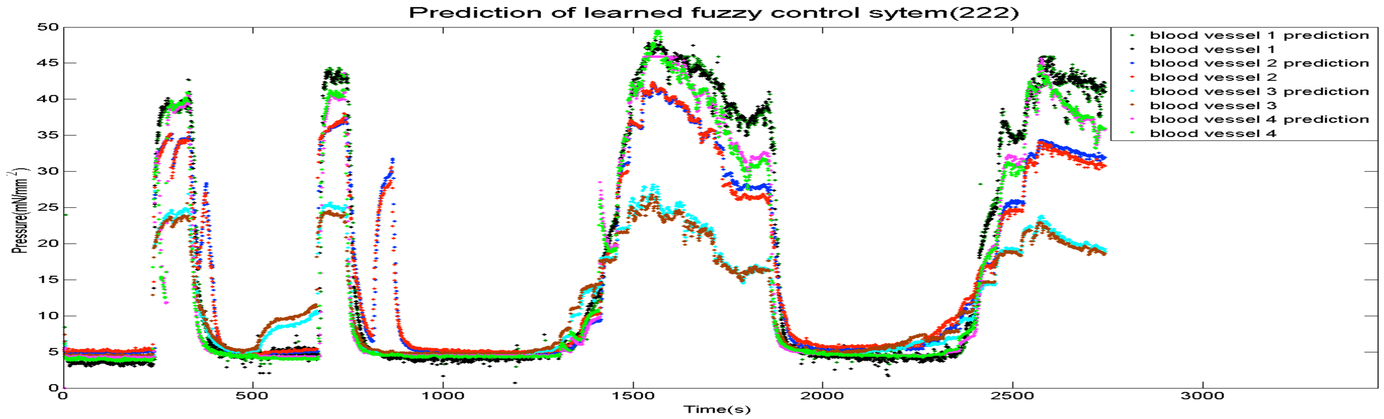



**Figure 1** Prediction of Fuzzy control system. There are four blood vessels; the experimental data generated of blood vessel 1 is used to train the fuzzy control system and the other three blood vessel are used to test the fuzzy control system

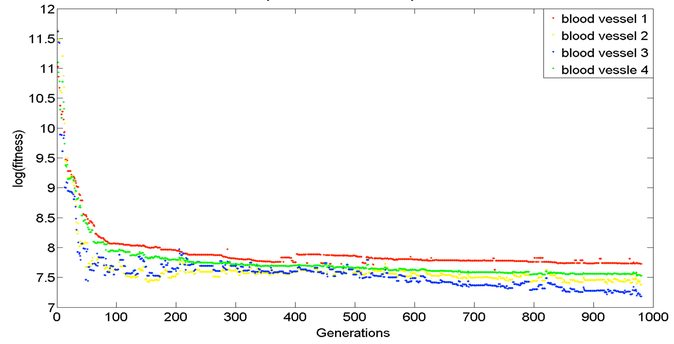



**Figure 2** Interpolation and extrapolation

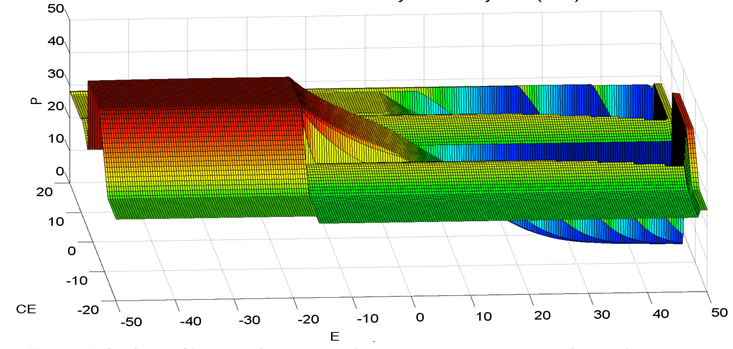



**Figure 3** Surface of learned fuzzy control system. Representation of the rule base and consequence (output) of the optimized Fuzzy System

## Implementation

Setting up structure of chromosome → Implementing GFS (GA +FS) → Learning data(Parallel computing) → Extrapolation and interpolation → Tuning of Fuzzy system

## Summary

- According to the result of tests, the genetic fuzzy system can be used to predict the complex adaptive behavior of vascular function by fuzzy rules, instead of mathematical modeling. The behavior of fuzzy system can be seen in **Figure 1** and **3**.
- In the learning process, the number of fuzzy set for each input and output can vary between 2 and 7. Nearly all the combinations have been tried and the simplest combination 222 fits the training data best.
- The data set with the highest pressure data pattern had been chosen as training data set, in order to include all data patterns in the training process. Surprisingly, the prediction of test data set is very well (see **Figure 2**) and seems even better than that of the training data set.
- The training process is computationally laborious, because of the size of training data set, the size of chromosome and other factors. Further research could focus on optimizing this process.

## Future work

- Process prediction with a random start in time series process could be our further work to extend the function of genetic fuzzy system. To achieve this prediction, additional input variable in needed for the fuzzy system and the system will be more complex.
- Chromosomes with variable length evolving in same population could be a solution to reduce the time in optimization.
- The application of GFS is our next step in future. As far as we think, it can be used to classify or cluster blood vessels on the basis of their characteristic behavior.